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No 8

The Canadian Nonferrous-Metals Sector

SECTORAL TECHNOLOGY STRATEGY SERIES

NO. 8 THE CANADIAN NONFERROUS-METALS SECTOR

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Highlights

- Canada's nonferrous-metals sector is among the largest in the world and has been critically important to the country's economic development. Canada is the world leader in value of mineral exports and ranks fourth among the diversified-minerals producers in nonfuel-mineral production. Overall, Canada enjoys an abundance of minerals and has a world-class nonferrous-metals sector.

- The Canadian nonferrous-metals sector is dominated by a few large, world-scale firms, most of which are vertically integrated through all stages of metal production.

- There are two strategic elements in the business operations of the nonferrous-metals sector:
  1) "upstream" exploration, mine development, extraction, smelting, and refining, where the emphasis is on being a low-cost, efficient, technically advanced, and environmentally sound producer; and
  2) "downstream" semifabrication and new-product development (the latter including new alloys and materials, and linkages to manufactured finished products), where the emphasis is on providing superior products with higher quality or better technology characteristics.
  The business strategies of Canadian firms have until now emphasized the upstream activities.

- These two strategic elements are clustered around two respective "core competencies":
  1) exploration and profitable mine development; and
  2) researching promising new materials and novel applications for old ones.

- The Canadian sector has expertise in both core competencies; however, it is the upstream one of exploration and mining that has been relatively more developed. Indeed, on this competence Canada is a world leader.

- Until recently, foreign, particularly U.S., tariffs for semifabricated products have been higher than tariffs for ore concentrates. In some other markets, notably Japan, tariffs apply at an even earlier stage to protect smelting and refining as well as fabrication. The higher tariffs have discouraged the development of value-added products in Canada's nonferrous-metals sector. Another limiting factor has been the reluctance of Canadian companies to compete with their own customers. Lower tariffs and the Free Trade Agreement between Canada and the United States should provide new opportunities for semifabrication and new-product development.

- The highly protected and small Canadian market also discouraged innovation and downstream development. A more dynamic and demanding manufacturing sector would have provided stronger motivation for new-product R&D.

- The amount spent on nonferrous-metals R&D in Canada is very low: at approximately 1 per cent of sales, the rate is lower than in virtually all competing countries. From the perspective of Canadian nonferrous-metals firms — with their upstream-oriented business strategies — the highly productive, automated mining processes used in Canada are evidence that current levels of R&D are appropriate.

- The Canadian sector argues that exploration is equivalent to R&D because it is as risky and as necessary an investment for the future. At present Canadian nonferrous-metals firms typically invest two to four times more in exploration than in R&D. If exploration expenses were included as R&D,

the Canadian total rate would be generally comparable to those of other competing countries. However, in light of both the development of advanced materials and the potential for material substitution, brought about by foreign research, there is debate whether it is reasonable to equate exploration with R&D.

- Some Canadian firms argue that they do not do more downstream R&D because, in their experience, it has not been profitable. One problem that Canadian nonferrous-metals producers face — one that helps explain poor experiences with downstream ventures — is the lack of close links in Canada between the metals suppliers and innovative downstream users, such as construction companies, automotive-parts firms, and electrical and electronics firms. Although some Canadian metals firms work with their customers to develop new products and applications, this cooperation is relatively limited and does not generally extend to shared equity positions or even joint strategic planning.

- The key issue is whether the Canadian upstream strategy will continue to offer adequate profits, domestic growth, and employment in the future.

- There are three broad scenarios for future development of the sector.
  1) In the "traditional" scenario, Canadian firms continue their upstream strategy but invest more intensively overseas.
  2) In the "incremental" scenario, each firm steadily builds on its existing technologies and core competencies, but it also gets involved in limited downstream integration.
  3) In the "downstream" scenario, firms develop new products and strong linkages to downstream manufacturing industries.

- Can the sector afford not to move toward a downstream strategy, which is arguably Canada's best opportunity for growth and increased employment in the nonferrous-metals sector? This approach would require major new investments, both to conduct necessary R&D and to establish closer links with downstream customers. And it would involve businesses in the risky strategy of venturing into unfamiliar territory instead of "sticking to their knitting." New North American trade arrangements heighten the opportunity, but there may also be need for governments to provide more supportive policies.

Background to the Sectoral Technology Strategy Series

In the emerging "new" economy of the 1990s, successful high-value businesses in advanced nations are being driven by innovation, propelled by spending on new products and processes. Their business strategies centre increasingly on specialized knowledge and skill in finding the right "fit" between their unique blend of core technologies and particular markets.

Where does Canada stand in this rapidly evolving new environment of changing linkages and relationships? The poor innovative capacity of Canadian industry has long been a concern of the Science Council of Canada, going back to its 1971 report *Innovation in a Cold Climate*. The Council re-emphasized this concern in 1988. It focused its attention on the potential for action at a sectoral level in its statement *A Sectoral Approach to Innovation*. It argued:

> There is growing recognition by industry and government in Canada of the key role played by technology and R&D in domestic and international competition. The Science Council considers that it is primarily the responsibility of industries to raise the degree of domestic technological sophistication and the level of R&D. Nevertheless, governments can help business to sustain long-term competitiveness both by building partnerships with individual firms and by generating consensus on the formulation of innovation strategies for the various industrial sectors. The intent is not for government to tell business what to do, but to facilitate business cooperation in a process of self-help. The process of building consensus on a strategy for a particular sector will involve close and on-going consultation with industries about the current role of technology and R&D in the sector, the opportunities foreseen, and the nature of the sources, stimuli, and forms of technological innovation. Obviously, to be successful, separate innovation strategies will be needed for each sector. The Science Council hopes that the process of building consensus will generate commitment and collective will concerning priorities, areas for cooperation, and agenda for action.

This statement proved to be an important step in the path that subsequently led the Council to undertake a major Sectoral Technology Strategy project.

In 1989, Industry, Science and Technology Canada, at a time of heightened concern for the state of Canadian competitiveness and serious questioning about the low level of Canada's gross expenditures on research and development as measured against other advanced countries, agreed to provide the main funding for this project. It also stipulated the selection of sectors on which it would like the project to focus.

Each report in this Sectoral Technology Strategy Series draws in part upon analyses commissioned by the Science Council of Canada from contractors, designed to reveal the key dynamics driving technological innovation in the sector and influencing company technology strategies. Each report has also benefited considerably from the comments and advice submitted by the many external reviewers from business, universities, and government, who are recognized in the Acknowledgements.

Commentary on the Sectoral Technology Strategy Series and R&D Targets

The Sectoral Technology Strategy Series has analysed 15 Canadian sectors. On the basis of this experience, the Science Council of Canada makes the following points with regard to Canadian R&D performance and the issue of setting sectoral R&D targets.

- Canadian firms, when grouped by sectors, generally perform much less R&D than their trade competitors. Using the indicator of R&D as a percentage of sales, Canadian firms undertake R&D at a rate about one-third to one-half the rate of their leading international sectoral competitors. The notable exception among those sectors analysed is telecommunications.

- In some product lines or specific technologies certain absolute threshold levels of R&D and capital investment must be reached if the effort is to be considered to have a chance of making a commercial payback. High thresholds are apparent in some parts of sectors such as telecommunications (central office switches), automotive parts ("Tier 1" supplier status), oil and gas (reformulated gasoline standards by refineries), and electronics (integrated circuit foundry). Such absolute thresholds cannot be clearly expressed as a percentage of sales.

- The reasons for the lower level of R&D spending by firms in most of the 15 Canadian sectors are: choice of business and technology strategy (which, in part, leave Canadian companies as essentially non-participants in many higher value-adding segments); the relatively small size of Canadian firms; the high absolute thresholds of R&D expenditure required to be a meaningful player, especially for innovative technology strategies; and the degree of foreign ownership of Canadian firms (especially important in the case of the automotive vehicles and parts sectors).

- The lack of R&D relative to other countries affects Canadian competitiveness, but it is only one of many factors, such as capital and labour costs, quality design, good marketing, and management, that interact to affect overall competitiveness. Nevertheless, the contribution of R&D, or more precisely, technology-based innovation, is becoming more pronounced throughout the global economy and Canada continues to fall behind. The low level of R&D is especially detrimental to the capacity of Canadian resource-based sectors to compete with higher-value, differentiated products, leaving them vulnerable to adverse shifts in costs beyond their control, such as a higher exchange rate.

- Major potential does exist for Canadian industry to make additional R&D investments. However, fulfilling this potential depends heavily on the vision and capability of management to make strategic use of technology, to speed the firms' innovation process, to work more closely with suppliers and "demanding customers" all the way to the end of the product chain, and to build core capabilities in incremental innovation and R&D. Canadian firms have not yet fully grasped the implications of the emerging new "lean enterprise" or "agile producer" strategy. To follow this new strategy involves seeking to offer maximum value to customers. It requires integrating the skills base of a knowledgeable workforce with flexible management structures that stimulate cooperative initiatives within and between firms to match customer needs.

- The dominant technology strategies being followed by Canadian firms in these sectors are of adopt and adapt. Innovation technology strategies are not very extensive (telecommunications is again an exception) and hardly any firms focus on breakthrough strategies to enhance competitiveness. Overall, these 15 sectors show little attempt at diversification out of existing product lines as opposed to making such products more efficiently.

- Governments can set sectoral R&D targets in the hope of stimulating enhanced industrial performance, shifts in business strategy, and greater commitment by the private sector to R&D. However, private sector R&D is only meaningfully undertaken in conjunction with a full complement of associated private and public sector actions ranging from improved design and production to finance and marketing. Doing more R&D will not be productive unless linked to a broader corporate technology strategy that is carefully designed to support the firm's business objectives. Otherwise, the corporation cannot, and will not, marshal the complementary investments required to reap the benefits of the R&D. It is the firm that must commit R&D resources.

- Setting sectoral R&D targets becomes more difficult as the boundaries between sectors are breaking down, through technological advances, regulatory change, and firm restructuring. Larger and more diversified firms that dominate modern industrial R&D perform R&D that might be allocated to any of several sectors. Examples include the textiles and materials R&D performed by large Japanese steel firms, the electronics R&D by automotive-vehicle firms, and the software R&D by telecommunications firms. Canadian governments have quite correctly encouraged higher levels of industrial R&D in Canada. In view of the rapid pace of scientific advances and technological change, plus the role of system interdependencies and synergies between technologies, setting R&D targets does not appear to be a task warranting the intensive effort, cooperation, and, ultimately, commitment that would be required by federal and provincial governments and private sector organizations.

List of Sectoral Technology Strategy Series Reports

No. 1 The Canadian Telecommunications Sector
No. 2 The Canadian Automotive-Parts Sector
No. 3 The Canadian Iron and Steel Sector
No. 4 The Canadian Automotive-Vehicle Sector
No. 5 The Canadian Oil and Gas Sector
No. 6 The Canadian Petrochemicals and Resins Sector
No. 7 The Canadian Banking Sector
No. 8 The Canadian Nonferrous-Metals Sector
No. 9 The Canadian Forest-Products Sector
No. 10 The Canadian Machinery Sector
No. 11 The Canadian Food and Beverage Sector
No. 12 The Canadian Electric-Power Sector
No. 13 The Canadian Consulting-Engineering Sector
No. 14 The Canadian Electronics Sector
No. 15 The Canadian Computer Software and Services Sector

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Introduction

Canada has long been known for its abundant material resources. Among the most successfully exploited Canadian materials are the nonferrous metals, such as nickel, copper, zinc, and lead. Nonferrous metals represent vital components of Canada's merchandise trade and provide a large export surplus for this country. A long-standing issue is whether Canada should continue to export nonferrous metals (and other materials) in their crude or semifabricated state rather than upgrading them to higher value products in search of greater benefit to the Canadian economy and overseas customers.

The main objective of this report is to indicate:

- the technology strategies of the leading firms;
- the sector's performance in R&D compared with that of our main trade competitors;
- the major reasons for any differences; and
- how these differences affect competitiveness.

A close look at the Japanese and Canadian nonferrous-metals sectors reveals how fundamentally different the two are and some of the reasons for their very different strategies and R&D performance. The report concludes with three broad scenarios for the sector's future: a "traditional" upstream-oriented view; an "incremental" view accepting the need for some integration into downstream activities; and a "downstream" view stressing a distinctly new direction and a different focus for R&D.

Overview of the Global Nonferrous-Metals Sector

The Global Nonferrous-Metals Sector

The nonferrous-metals sector includes all the metallic minerals except iron. These metals fall into three categories: base metals, such as nickel, copper, lead, and zinc; light metals, such as aluminum and magnesium; and precious metals, such as gold, silver, and platinum. A separate study in this series covers the ferrous metals: see Science Council of Canada Sectoral Technology Strategy Series, No. 3: *The Canadian Iron and Steel Sector*.

The nonferrous-metals sector engages in three key activities:

- *Mining* — Mining includes exploration, development, extraction, and beneficiation. Exploration is the process of searching for mineral occurrences and identifying and evaluating ore deposits. Development involves all the work necessary to make extraction feasible. Extraction is mining and treating the ore, often including its host rock. Practically, extraction includes opencast work, quarrying, alluvial dredging, and combined operations such as surface and underground attack and ore treatment. Beneficiation is the dressing or processing of ores to: a) regulate the size of a desired product; b) remove unwanted constituents; and c) improve the quality, purity, or assay grade of a desired product.
- *Smelting and refining* — Smelting transforms metal concentrates into crude metal, whereas refining upgrades the purity of the metal. Output is in the primary forms of ingots, pigs, billets, and slabs.
- *Semifabrication* — Semifabrication is the manufacture of rolled, extruded, and cast products from aluminum, nickel, copper, zinc, lead, and alloys. Products are in the form of sheets, strips, bars, rods, powders, cast shapes, pipes, tubes, and other extrusions. Rolled and extruded products are usually intermediate products to be processed further by other manufacturers. Cast products are typically parts to be incorporated into final products.

Ownership and control of world mining are concentrated in a few multinational mining firms (most of which are privately owned) and in state mining enterprises. The multinational firms have their headquarters in the United States, Canada, Australia, South Africa, or one of the Western European countries. These firms have mining and refining operations all over the world. The state mining enterprises are typically headquartered in less-developed countries and usually remain within domestic boundaries.

There are also thousands of small, privately owned mining firms in the developed countries and in some of the Third World nations (for example, in Latin America: Brazil, Chile, Mexico, and Peru). However, small mines produce less than 25 per cent of the world output. Their main activities tend to involve gold, silver, and diamonds and other precious stones. Small mines also concentrate on types of mining in which economies of scale are less important.

There are two strategic elements in the business operations of the nonferrous-metals sector:
1) The "upstream" activities are mining (including exploration, development, extraction, and beneficiation), smelting, and refining. The skills and technology required for these activities typically include geophysical exploration techniques, drilling, mine development, and state-of-the-art processing techniques for concentration, smelting, and refining.
2) The "downstream" activities are semifabrication and the development of new products (including alloys and materials) and establishing linkages to manufactured finished products. The skills and technology required for these activities typically include R&D on promising new alloys or materials and identifying novel applications for existing products.

Some firms in the sector are "integrated"; that is, they undertake the full range of activities listed here. Others tend to specialize. In Canada, for example, Inco, Noranda, and Falconbridge are

integrated companies, with facilities for smelting, refining, and semifabrication, whereas firms such as Rio Algom and Placer Dome are primarily mine producers.

The Global Nonferrous-Metals Market

Demand for most nonferrous metals tends to be concentrated in a few highly cyclical sectors of the economy: construction, capital equipment, transport, and consumer durables. This demand is also noted for its volatility. Metals' demand tends to lag behind economic (business) cycles by 12 to 18 months.

Despite fluctuations, the rate of overall Western world consumption of almost all the major metals grew briskly from the postwar period until the early 1970s, when there was a sharp drop (see Table 1). The rates of growth of global demand for major metals also declined from the mid-1970s to 1985. Western consumption of zinc actually shrank, and none of the other major nonferrous metals — aluminum, copper, and nickel — was spared.[1]

The substantial slowdown in the growth of world demand for metals after 1973 had not been anticipated. Indeed, until 1979, the prevailing view was that the world faced mineral and material shortages, not gluts, for the foreseeable future. Even after 1980 and the collapse of many commodity markets, it was widely assumed that demand for metals was simply going through another cyclical downturn: the world economy would recover, and the growth rate of metal consumption would return to its former, almost exponential, trajectory.

New capacity was planned and built that would be sufficient to satisfy an assumed resumption of the previous growth in demand. Even after this assumption became untenable, new capacity already under construction continued to come on stream for some time. The result in the early and middle 1980s was a sizable overcapacity in nonferrous metals, a sharp drop in metal prices, and much lower profits for mineral producers.[2]

After 1985 the fortunes of nonferrous-metals producers improved. Growth in the world market brought capacity more in line with demand. In fact, for zinc and copper, smelting capacity was barely sufficient in 1990, and nickel was in short supply in 1989. The recession that most countries suffered in 1990-1991, however, put the Canadian, U.S., and Australian sectors back into a generally surplus position and accordingly put downward pressure again on costs and prices. Indeed, since the mid-1960s the trend in average prices of major minerals and metals in constant dollars has been flat or even downward, and costs have also dropped.[3]

Nowhere in the developed world has the slowdown in the sector been more severe than in North America. Whereas Western world consumption as a whole experienced substantial growth from 1950 to 1974 and then slower growth through the 1970s and 1980s, the North American metals markets have grown very little or stagnated since the 1950s. This is understandable, as North America tends to be the high-cost production area.

North America's share of Western world consumption of metals dropped substantially from 1950 to 1987. Among steel and four major metals — aluminum, copper, nickel, and zinc — the largest drop, from 73 per cent to 26 per cent, was in nickel, and the smallest drop, from 53 per cent to 30 per cent, was in copper.[4]

Lower growth in gross domestic product (GDP) and declining intensity of use since 1973 have both affected the demand for metals. However, the declining intensity of use has had the most effect (see Table 1): the Western world is getting by with less metal in its unit output.

Despite cyclical upturns, during the past 20 years the mining and processing subsectors of the metals sector in both Canada and the United States have struggled with excess supply, overcapacity, cheaper overseas production, low profits, and plant closures. There have been a few bright spots: gold mining and exploration have generally done well (although even in this case real prices have fallen a

Table 1. Growth of Western world metal consumption, intensity of use, and gross domestic product (1960-1973 and 1973-1985)

Metal and Period	Annual growth in metal consumption (%)	Annual change in intensity of use (%)	Real annual growth in GDP (%)	Projected 1973-1985 metal consumption, assuming 1960-1973 growth, in:	
				Intensity of use* (%)	GDP† (%)
Aluminum					
1963-1973	9.9	4.5	5.2		
1973-1985	1.2	-1.3	2.6	7.2	3.8
Copper					
1960-1973	4.6	-0.6	5.2		
1973-1985	0.4	-2.1	2.6	2.0	3.0
Nickel					
1960-1973	6.8	1.5	5.2		
1973-1985	0.9	-1.6	2.6	4.1	3.5
Zinc					
1960-1973	5.4	0.1	5.2		
1973-1985	-0.3	-2.8	2.6	2.7	2.3

Sources: Metal consumption data are from *Metal Statistics*, published annually by Metallgesellschaft Aktiengesellschaft, Frankfurt, Germany; and from *Steel Statistical Yearbook*, International Iron and Steel Institute, Brussels, Belgium. Gross domestic product (GDP) data are from the World Bank, *World Bank Data Tape: National Accounts, Prices, Exchange Rates and Population for the Period 1960-84*, Washington, D.C., 1987.

* This column indicates the projected rate of growth of metal consumption that would have occurred from 1973 to 1985 had intensity of metal use continued to grow during this period as much as it did from 1960 to 1973.

† This column indicates the projected rate of growth of metal consumption that would have occurred from 1973 to 1985 had Western GDP continued to grow during this period as much as it did from 1960 to 1973.

great deal in the last 10 years), and metal prices generally recovered in the late 1980s. Nevertheless, few would refer to the period since 1973 as the golden age of the North American metals sector.[5] Canada, in particular, suffered from its recent experience with a rising exchange rate.

During this prolonged period of slow growth in Western consumption of metals, the marginal producers (those with the highest costs) suffered most. In the case of nickel, producers in less-developed countries closed first: extraction of nickel ore in the oxidized form, typical of deposits in tropical countries, is highly energy and oil intensive. However, in other cases North American operations were the first to cut back on production.[6]

Copper provides an excellent example. Western copper capacity expanded continuously from 1974 to 1984 and was more than 20 per cent greater in 1984 than a decade earlier. Copper

consumption, on the other hand, increased by only 11 per cent. And copper capacity declined in both the United States and Canada during the same period.

A contributing factor to the reduction in North American capacity has been more stringent environmental standards. Certainly, in the United States, the government's limitations on sulphur dioxide (SO_2) emissions have affected the copper industry. "During the 1980s several US copper smelters closed because they did not meet Environmental Protection Agency (EPA) pollution abatement standards."[7] Companies who chose not to undertake the necessary modifications were forced to leave the market. Often these companies had smaller or older facilities whose throughput could not justify the large investments required.

In many developing countries, governments have operated copper mines with little concern for the long-run global demand for, and supply of, copper. This is recognized as contributing to the poor performance of the copper industry. For example, the state-run Zambian Consolidated Copper Mines (ZCCM) has pursued social objectives, such as maintaining the employment of Zambians, at the expense of profit maximization.[8] ZCCM produced without regard to cost, to the detriment of other producers.

Fortunately, even the state-run enterprises in the developing world are now responding to the market and the environment. The cost of subsidies has become prohibitive, and obtaining international financing now sometimes depends on achieving targets in environmental protection.

On balance, real metal prices are not likely to rise significantly in the foreseeable future. Overall, nonfuel minerals are still abundant, and none of the major minerals has become increasingly scarce.[9] Moreover, it is unlikely that growth in demand for nonferrous metals will ever return to its pre-1970 levels.

Competitive Trends in the Global Nonferrous-Metals Sector

Competition from Low-Cost Production

An important challenge to the nonferrous-metals sector of the developed world is competition from low-cost production in developing countries. Production of commodities for world markets has been gradually shifting from the United States, Canada, and Western Europe to countries with higher grade ores or lower wages. For example, there has been a shift in production of copper, lead, zinc, and iron ore to Brazil, Chile, and the countries of the Pacific Rim. A larger share of the world copper market could be supplied by Chile, Zambia, and Zaire, which have the highest grade copper in the world (outside of a very rich deposit in Portugal). Some developing countries that have so far concentrated on commodities are now integrating downstream to the production of aluminum, steel, and a variety of fabricated and manufactured metal products.[10]

Low-cost production in the countries of the former Soviet Union may also present a challenge. Those countries may try to expand production to earn hard currency. They have major mineral resources, and if they can overcome current disruptions they may eventually offer substantially more supply to the world market. This might constitute new competition for the Canadian sector. On the other hand, Canadian firms might benefit from such a situation by exporting their world-class expertise in exploration, mine development, and processing techniques to help put those countries back on their feet.

Competition from Value-Added Products

Globally the nonferrous-metals sector has been a commodity sector, focused on mass production of undifferentiated products at the lowest cost. Recently, however, many firms worldwide have begun to concentrate more of their R&D efforts on semifinished to finished metal products.

Nowhere is this more apparent than in Japan. In fact, the downstream end of the nonferrous-metals sector is increasingly dominated by Japanese companies. Japan has few mineral resources, but it has a huge domestic market for metals products. This, coupled with the world's highest electricity costs, has provided the incentive for Japanese metals companies to invest heavily in R&D to add value to the minerals and commodity metals they purchase overseas.

In Japan, raw materials account for 70 per cent of all manufacturing costs within the nonferrous-metals sector (energy accounts for 24 per cent; labour, only 6 per cent)[11], so dependence on imported metal or concentrate leaves Japanese metal companies somewhat vulnerable to commodity price swings. Nonetheless, the Japanese nonferrous-metals sector is growing steadily, driven by the presence of world-class end-users such as the electronics and automotive-vehicle industries. Thus, despite the lack of domestic mineral resources, Japan is a major producer of refined nonferrous metals (see Table 2a). In fact, Japan produces as much as Canada. Japan is also a massive consumer of ore concentrates and refined products. It is the world's largest importer of copper concentrates and also a key buyer of refined aluminum and nickel. Japanese companies have been taking equity interests in foreign mining operations as well as smelters.

Moreover, during the current economic downturn, Japan has actually gained market share as compared with Canada (Table 2b).

Table 2a. World production of refined nonferrous metals and Japan's and Canada's shares (1988)

Nonferrous metal	World total (million tonnes)	Japan (%)	Canada (%)
Copper	11.1	8.9	9.0
Lead	5.7	4.7	4.8
Zinc	7.25	9.3	8.0

Source: Corporate Directions Inc., "The Japanese nonferrous metals industry, industry structure and technology strategies," contract report prepared for the Science Council of Canada, 1990 (unpublished), 6.

Table 2b. World production of refined nonferrous metals and Japan's and Canada's shares (1990)

Nonferrous metal	World total (million tonnes)	Japan (%)	Canada (%)
Copper	10.74	9.7	8.3
Lead	5.67	5.8	3.4
Zinc	7.11	9.7	8.3

Source: Figures provided by Energy, Mines and Resources Canada

The presence of major downstream industries benefits the Japanese metals producers. For example, consider the processing of copper ore. Besides actual copper, the processing produces slag and sulphuric acid by-products. The presence of commercial markets in Japan for these by-products improves the overall return on Japanese investments in processing.

The Japanese currency, the yen, has generally appreciated over the last 20 years. The real cost to Japan of imported raw materials is accordingly being reduced over time, even though yen revaluation makes Japanese final products more expensive as exports. This revaluation process strengthens the Japanese strategy of linking metals production to finished products, as Japan's "terms of trade" are improving.

Semifabrication in nonferrous metals is a large-scale and rapidly growing activity, supplying Japan's powerful end-user industries (see Table 3).

A major trend in the Japanese nonferrous-minerals sector is toward the production of higher value-added products (for example, copper foil). This trend provides new sources of profit and reduces the industry's vulnerability to commodity price swings. The Japanese are also developing export markets in the high-growth Asian economies (Taiwan, Korea, Singapore, Thailand).

The Japanese concentration on value-added products places a premium on R&D. As a result, Japanese nonferrous-metals companies have substantially increased their R&D funding. Their R&D expenditure grew from U.S.$457 million in 1981 to U.S.$813 million in 1988. R&D expenditures in the nonferrous-metals sector have reached 2 per cent of sales.[12]

The Japanese sector has invested heavily in semifabrication technology. Indeed, semifabrication accounts for 70 per cent of R&D expenditures; smelting and refining, for 25 per cent;

Table 3. Semifabrication in Japan's nonferrous-metals industry (1988)

Nonferrous metal	Semifabricated product	Production (thousand tonnes)	End uses
Copper	Wire	1 020.1	Communications wire (60% of demand)
	Rolled	455.9	
	Others	22.0	
	Total	1 498.0	
Zinc	Total	760.2	Zinc-coated steel sheets for car bodies
Lead	Battery components	188.0	Car batteries (60% of demand)
	Pipe	10.9	
	Others	94.9	
	Total	293.8	
Aluminum	Rolled	926.4	Almost exclusively processed from imported aluminum: for cars, window sashes, cans
	Extruded	1 118.2	
	Wire	77.3	
	Total	2 121.9	

Source: Corporate Directions Inc., "The Japanese nonferrous metals industry, industry structure and technology strategies," contract report for the Science Council of Canada, 1990 (unpublished), 17.

and mining, for 5 per cent. R&D efforts are also focused on development (5 per cent on basic research, 30 per cent on applied research, and 65 per cent on development).[13] The government funds only 5-10 per cent of this R&D activity; most of the government's R&D support is for basic research.

Historically, the balance between product- and process-related R&D has fluctuated, but the Japanese nonferrous-metals sector today is clearly focused on the development of new products. A manager from Mitsubishi Metals summed up the Japanese approach to R&D in an interview for this report: "Even though conventional business operations account for 50 per cent of our total revenues, they only receive 10 per cent of our R&D budget. The other 90 per cent goes to new areas, mainly new material and new product development."[14]

The main driver of Japanese new-product technology is a sophisticated and expanding end-user markets. Key users of nonferrous metals include the electronics and automotive-vehicle industries. There is a high level of competition among major Japanese nonferrous-metals companies, all of which are materials companies not overly specialized in one commodity. Suppliers and customers have a mutually supportive relationship: a level of de facto vertical integration is a major factor in Japanese success. It should be heavily emphasized that this supportive relationship works both ways: customers encourage the materials companies to develop better products, and the materials companies encourage their customers to buy them. (See Science of Canada Council Sectoral Technology Strategy Series, No. 2: *The Canadian Automotive-Parts Sector*; No. 3: *The Canadian Iron and Steel Sector*; and No. 4: *The Canadian Automotive-Vehicle Sector*.)

Thus, the Japanese and Canadian nonferrous-metals sectors are fundamentally different, driven by different resource and market opportunities. The Japanese focus is downstream, whereas the Canadian focus is upstream.

Japanese metals firms are not the only ones aggressively pursuing a downstream strategy. Another example is the Finnish company Outokumpu Oy. In recent years Outokumpu has strengthened its upstream resource base through investments in overseas mines because Finland is depleting its domestic sources. But, like Japanese companies, Outokumpu has also aggressively pursued downstream integration into value-added products in both domestic and, more importantly, overseas markets, like the United States. Outokumpu has also successfully developed new technology and marketed it worldwide. The Japanese metals companies may be the farthest along on the downstream and new-product road, but they are not the only ones moving in that direction.

Competition from Substitutions

The markets for nonferrous metals are subject to substitution by other materials.

There are specialized uses for each of the major nonferrous metals. For example, copper is used primarily in electric wiring, owing to its high electrical conductivity. Lead is used in batteries because it reacts well with chemical electrolytes. Zinc is used for coating steel sheet because it resists corrosion. Nickel is used in steel alloys to make stainless steel. In almost all cases, one single, specialized application accounts for half or more of total consumption.

Many of the world's nonferrous-metals companies have specialized in mining and processing a particular commodity. Even today many firms specialize in one or a few minerals. Examples are Alcoa (United States) and Alcan (Canada), which specialize in aluminum; Kennecott (United States), which focuses on copper; Cominco (Canada), which specializes in lead and zinc; and Inco Limited (Canada), which is a leader in nickel, as its former name — the International Nickel Company — suggests. Specialization allows a company to develop expertise in a particular commodity, but it also leaves the company vulnerable to substitutions.

Over the past two decades, the demand for metals has been decreasing, in part because of substitution by plastics, composites, and other new materials and the use of thinner gauges. For example, the decline in the intensity of use of copper can be attributed to: a) the use of fibre optics in telephone trunk lines and feeder networks; b) the use of new aluminum alloys for electricity networks; c) increased use of plastic tubes in construction; d) the use of aluminum radiators in vehicles; and e) gauge reductions in wiring cables for automotive and domestic use and in magnetic wire.[15] Who remembers today that in 1973 Canada's largest export by value was copper?

Aluminum and zinc are also facing competition from plastics, composites, fibres, other metals, microminiaturization, thinner gauges, and improved manufacturing techniques. The replacement of steel by plastics in vehicle bodies will reduce demand for zinc, which is used in rust-resistant coatings.

Major material substitutions have already been made in two recent automotive products from Japan and another from the United States. The new Acura NSX sports car from Honda of Japan uses a very high proportion of aluminum in its body panels and structure. Although this vehicle is expensive by current standards, it suggests possibilities for the use of aluminum in mass-produced cars. Perhaps even more interesting are the Honda CRX from Japan and the new "Saturn" line of cars from General Motors in the United States. These use a high proportion of plastic materials in their body panels and are low-cost automobiles by current standards. It is noteworthy that in order to use plastic body panels, new technology had to be developed to ensure that flat plastic sheets would be rigid enough.

Moreover, it is in the interests of major raw-material importers (like Japan) to do the research to encourage substitution. If any one commodity becomes indispensable, then importers would be

vulnerable to oligopolistic cartels raising the price by agreement — exactly what the Organization of Petroleum Exporting Countries (OPEC) succeeded in doing for petroleum in the 1970s. Accordingly, industrial nations that rely on imports can be counted on to maximize the opportunities for substitution.

In North America, on the other hand, virtually all nonferrous minerals have been close at hand. There had been little pressure for substitution, so nonferrous-metals firms still specialize in one or two commodities. Japanese success in the nonferrous-metals sector suggests, however, that the real challenge North American companies face is to develop a business and technology strategy that emphasizes advanced materials and new products, not the production of commodities.

No doubt the future will bring more substitutions, such as ceramics and titanium. Ceramic material (for example, silicon nitride) might be commercially formed in part from sand. Advanced ceramics might be extremely heat resistant and hence allow the use of adiabatic engines — engines without a cooling system. Such engines would be very fuel efficient, a desirable feature impossible to obtain to the same degree solely with metals. Iron, steel, and even aluminum could be displaced by such a technology.

The metallic element titanium is in its infancy as an industrial material. At present it is used mostly in high-value, specialized applications ranging from artificial limbs to jet aircraft. Titanium is inherently stable and hence resists most re-forming processes. Generally it is only worked in a very sophisticated electric plasma-arc furnace — at very high cost. Yet its properties offer high potential: it cannot rust, it resists deformation by high temperatures, and it has an exceptionally high strength/weight ratio. It is also very abundant in Canada and elsewhere. If cheaper processing could be invented, titanium could conceivably take markets away from iron and steel, aluminum, nickel, and other commodities.

Overview of the Canadian Nonferrous-Metals Sector

Canada's nonferrous-metals sector is among the largest in the world and has been critical to the country's economic development. Canadian companies have ready access to domestic mineral resources, inexpensive electrical power, and proximity and access to the large U.S. market. Canada leads the world in value of mineral exports and ranks fourth among the diversified-minerals producers in nonfuel-minerals production, behind the former Soviet Union, the United States, and South Africa[16] (see Table 4). Canada's international ranking as a mineral producer has slipped in the past decade, however, as costs have escalated with high interest rates, a strong Canadian dollar, and high wages.

Canada is a major world producer of most nonferrous metals. This is the largest sector of our minerals industry, constituting 65 per cent ($12.5 billion) of the total production value of all nonfuel mining ($19.2 billion) in 1988.[17] The nonferrous-metals sector is big business in Canada.

Although the economic contribution of the mining and metallurgy industries has been declining in Canada while the manufacturing and service sectors have grown, mining and metallurgy still represent a major proportion of total GDP (more than 4 per cent) and of total exports (13 per cent). In some regions of Canada, mining is virtually the only viable economic activity.[18]

The Canadian sector is dominated by a few large, world-scale firms. These firms are vertically integrated through all stages of metals production (see Table 5).

They are also global companies that operate around the world. For instance:

- Inco Limited operates a nickel smelter in Indonesia, and Falconbridge operates one in the Dominican Republic; both are based on lateritic nickel ore and both use a unique technology developed in Canada.

- Falconbridge's only nickel refinery is in Norway.

- Noranda operates a fully integrated aluminum business in the United States that includes a primary smelter and several rolling mills and fabricating operations.

- Alcan has extensive international operations, including Nippon Light Metals Company Ltd., a joint venture in Japan.

- Cominco has a 45 per cent interest in Mitsubishi Cominco Smelting Company, which operates the Naoshima lead smelter, and a 40 per cent interest in the Cominco Binani Zinc Limited zinc smelter in India. It also has interests in the United States, the United Kingdom, Spain, and Chile.

In addition to the large, integrated firms, there are many junior companies. These are strongly supported by a highly competitive and successful mapping and surveying industry. These smaller companies make important contributions to the sector, particularly in exploration. For example, the Louvicourt polymetallic sulphide deposit discovered by Aur Resources at Val-d'Or is the largest of its type found in Canada since Kidd Creek was discovered in the early 1960s.[19] In the short term, investment in a good orebody can prove highly profitable.

Although they are vertically integrated, the large Canadian firms, with the exception of Alcan and Sherritt Gordon, concentrate on the upstream segment of the mining industry. Mining activities make up more than 63 per cent of the value of sector shipments, with smelting and refining representing 27 per cent, and semifabrication only 10 per cent.[20]

Table 4. Canada's world role as a producer of certain important minerals (1990)

	World	Rank of five leading countries				
		1	2	3	4	5
Uranium (U concentrates)*		**Canada**	Australia	U.S.	Namibia	Niger
tonnes	29 961	10 118	3 530	3 430	3 211	2 830
% of world total		33.8	11.8	11.4	10.7	9.4
Zinc (mine production)		**Canada**	U.S.S.R.	Australia	China	Peru
thousand tonnes	7 414	1 176	940	925	620	582
% of world total		15.9	12.7	12.5	8.4	7.9
Titanium concentrates† (ilmenite)		Australia	**Canada**	Norway	S. Africa	Malaysia
thousand tonnes	5 667	1 622	1 025‡	875	700§	460
% of world total		28.6	18.1	15.4	12.4	8.1
Nickel (mine production)		U.S.S.R.	**Canada**	New Caledonia	Australia	Indonesia
thousand tonnes	873	210	197	89	68	54
% of world total		24.1	22.6	10.2	7.8	6.2
Platinum-group metals (mine production)		S. Africa	U.S.S.R.	**Canada**	Japan	Columbia
kilograms	267 646	130 635	121 304	11 210	2 177	809
% of world total		48.8	45.3	4.2	0.8	0.3
Aluminum (primary metal)		U.S.	U.S.S.R.	**Canada**	Australia	Brazil
thousand tonnes	18 173	4 048	2 380	1 567	1 233	931
% of world total		22.3	13.1	8.6	6.8	5.1
Lead (mine production)		Australia	U.S.S.R.	U.S.	China	**Canada**
thousand tonnes	3 405	564	500	475	341	232
% of world total		16.6	14.7	14.0	10.0	6.8
Cobalt (mine production)		Zaire	Zambia	U.S.S.R.	**Canada**	Cuba
tonnes	24 536	9 311	4 488	2 850	2 291	2 000
% of world total		37.9	18.3	11.6	9.3	8.2
Copper (mine production)		Chile	U.S.	U.S.S.R.	**Canada**	Zambia
thousand tonnes	9 173	1 588	1 578	950	802	516
% of world total		17.3	17.2	10.4	8.7	5.6
Cadmium (refined production)		U.S.S.R.	Japan	Belgium	U.S.	**Canada**
tonnes	20 602	2 600	2 491	1 958	1 912	1 458
% of world total		12.6	12.1	9.5	9.3	7.1
Silver (mine production)		U.S.	Mexico	Peru	U.S.S.R.	**Canada**
tonnes	14 470	2 083	1 955	1 780	1 500	1 400
% of world total		14.4	13.5	12.3	10.4	9.7
Gold (mine production)		S. Africa	U.S.S.R.	U.S.	Australia	**Canada**
tonnes	1 995	601	280	272	232	165
% of world total		30.1	14.0	13.6	11.6	8.3

Source: Energy, Mines and Resources Canada and Mining Association of Canada, *Mining in Canada: Facts and Figures*, Toronto, 1990, 8.

Note: All values are preliminary.

* Total of production from outside former Communist countries
† 1988 data
‡ Titaniferous slag with 80% TiO_2 content
§ Titaniferous slag with 85% TiO_2 content

Table 5. Leading Canadian nonferrous-metals firms (1990)

Canadian firm	World revenue ($ billion)	Mining	Smelting and refining	Semifabrication
Alcan	10.4	X	X	X
Inco	3.6	X	X	X
Falconbridge	2.0	X	X	X
Cominco	1.4	X	X	Nil
Noranda	2.7	X	X	X
Sherritt Gordon	0.3	Nil	X	X

Source: Energy, Mines and Resources Canada and Canada Consulting Cresap, "Mining and mineral processing: in-depth analysis," contract report prepared for the Science Council of Canada, 1990 (unpublished), 17-18.

As well, most of the major firms are specialized. Alcan, of course, specializes in aluminum; Inco and Sherritt Gordon, in nickel, lead, and zinc; and Cominco, in lead, copper, and zinc.

There are exceptions to this emphasis on commodity specialization. Noranda provides an example. Until the 1970s, Noranda specialized in copper. But the company diversified, and today its largest commodity production is zinc. Noranda has also purchased a major interest in a forest-products company, MacMillan-Bloedel Limited. In an equal partnership with an European firm, it has taken a 50 per cent ownership stake in a related but different metals company, Falconbridge. Noranda has also tried to create a new business venture built around the light metal, magnesium. Canada has considerable reserves of this metal and low-cost electric power for processing it. Noranda also has a subsidiary company, American Racing Equipment, which produces and markets magnesium wheels for high-performance cars.

Canada's nonferrous-metals sector grew rapidly and built a substantial competitive edge primarily in the 1950s and 1960s, when conditions were particularly supportive. In the past decade, however, the sector has been struggling against a series of difficulties, raising the need for massive new investments in technology and equipment to improve productivity and satisfy environmental regulations. This new investment is needed at a time of high capital costs, very low profits, and limited cash availability.

The recent and current financial status of the Canadian nonferrous-metals sector is mixed. For instance, according to data from annual reports, the total financial assets of four of the major firms have stagnated overall in real terms over the last 10 years (see Table 6). Of course, individual firms have different accounting bases, and their real assets (for example, changes in minable mineral reserves) may not always be captured in financial statements. The firms may also be in different segments of their investment cycles. Nevertheless, the figures indicate a stagnant real-asset base. The year 1991 was particularly bad for the sector: many firms, hit hard by declining copper, zinc, nickel, and gold prices, lost money.

Total employment in the sector has dropped sharply, which in part reflects the slow productivity growth. However, with sales in real terms (in 1981 constant dollars) also flat, this is definitely not a growth sector.

An important issue for Canadian firms is whether the business strategy they favour today — concentrating on upstream commodity production as opposed to an approach incorporating more downstream value added — will be the optimum for the future.

Table 6. Financial and employment data for four major Canadian metals firms (1981, 1990)

Company	Total sales (billion current $)		Total employment		Total assets (billion $)		Real 1990 total assets	Change in real assets 1981-1990
	1981	1990	1981	1990	1981	1990	(billion 1981 $)	(%)
Alcan*	5.0	8.8	67 000	57 000	6.3	10.6	7.2	+14
Inco*	1.9	3.1	32 000	19 000	3.9	4.1	2.8	-28
Falconbridge†	0.7	2.0	10 000	9 300	1.3	2.6	1.8	+38
Cominco	1.4	1.4	13 000	8 000	2.0	2.5	1.7	-15
Total			122 000	93 300	13.5	19.8	13.5	Nil

Source: Annual reports

* Annual report figures are in U.S.$
† 1989 figures are used for 1990 columns

Mining

Canada is a leading world player in the mining sector. Nickel, copper, gold, lead, and zinc are the major nonferrous metals mined in this country.

Mined ore is a commodity, the quality of which depends on ore-grade specifications. At this stage of production, competition is based on price, and innovations are oriented toward reducing costs. Costs in mining are influenced by labour rates, efficiency, and mining technologies. Labour represents 50 per cent of the operating costs in the average mine but can be as low as 30 per cent in mines using state-of-the-art technologies. This is a capital-intensive business. Other factors influencing costs include proximity to refining facilities and to end markets. A growing portion of the competition comes from developing countries with low wages, so Canadian companies are under intense pressure to invest in the best technology to achieve maximum improvements in productivity and to limit costs.

Smelting and Refining

Aluminum, zinc, lead, copper, magnesium, and nickel are the major nonferrous metals smelted and refined in Canada. Smelted and refined metals are still commodities. Competition is based mainly on price, which pressures competitors to reduce costs. Operating costs for smelting and refining base metals vary. Smelting and refining aluminum and magnesium require a great deal of energy. Canada's low electricity prices draw imported materials to Canada for processing. Rough breakdowns of operating costs show labour at 30-40 per cent, raw materials at 40-50 per cent, and energy at 10-20 per cent. (Aluminum and magnesium have higher energy costs of the order of 30 per cent.)

Case Study: Nickel

In many respects, the challenges faced by the nickel-smelting and -refining industry are the same as those faced by the entire Canadian smelting and refining sector: a declining share of the world market, competition from low-cost producers in the developing world, and the need for R&D into new, value-added products.

Three Canadian companies smelt or refine nickel: Inco, Falconbridge, and Sherritt Gordon. Smelting transforms nickel concentrates into crude metal, and refining upgrades the purity of the metal. Nickel is principally used in alloys for its ability to impart strength, toughness, corrosion resistance, and other physical properties. Sixty-four per cent of this metal is used in the production of stainless steel.

Inco Limited, the largest producer in the world, is fully integrated in its Canadian operations. It processes its ores from 17 mines in Ontario and Manitoba through two smelter-refinery facilities in Sudbury, Ontario, and Thompson, Manitoba. Falconbridge Limited, the second-largest nickel producer in Canada, smelts concentrates in Sudbury. Sherritt Gordon Limited, which has no nickel-mining operations, purchases nickel-bearing concentrates from various sources and processes these into nickel powder and briquettes at Fort Saskatchewan, Alberta.

In the 1950s, Canada typically accounted for more than 80 per cent of Western nickel production. This has fallen substantially, and the best available estimate is that Canada now produces about a quarter of the world's nickel. Canadian nickel shipments for 1986 were about $1 billion, of which 95 per cent was exported.

As Canada's share of the world market fell from about 85 per cent to 23 per cent its role changed from dominant supplier and price setter to swing supplier. This change is attributed to the emergence of the newly industrialized countries in the world nickel market and to the increase in state ownership and control of production during the 1970s and 1980s. (More than 40 per cent of world production capacity is now either directly or indirectly state-controlled.)

Although costs are site specific, it is generally acknowledged that sulphide nickel producers (such as those in Canada and Australia) have lower costs than the lateritic nickel producers (those in tropical countries). The production costs for lateritic nickel are estimated to be 1.2 times higher, due in large part to the energy required to smelt nickel. Energy constitutes about 60 per cent of the production cost of lateritic nickel and only 15 per cent of the production cost of sulphide nickel. If low-cost hydro power is available, however, lateritic producers can gain a competitive edge, depending on the process they use for smelting.

Another advantage enjoyed by sulphide nickel producers, such as those in Canada, is the by-product credits they receive from the sale of copper, cobalt, platinum-group metals, and other precious metals.

Labour costs are still a substantial portion of the Canadian operating costs, representing about 40 per cent, down from 50 per cent a few years ago. Although Canadian wages are notably higher than those in countries that produce lateritic nickel, a well-trained workforce, improved underground mining methods, and modern processing facilities give the Canadian industry its competitive operating cost per unit.

Canadian environmental regulations represent an additional cost that some foreign producers do not as yet have. Control of SO_2 emissions will require substantial capital expenditures and raise operating costs at domestic smelting operations.

Inco Limited has traditionally been a world leader in the development of both new production processes and new applications for nickel. In recent years, however, the company has been concentrating its R&D efforts on new technologies in mining, milling, and smelting. Only recently has it resumed efforts in product development. Sherritt Gordon has been the world leader in developing hydrometallurgical processes, and through its WESTAIM initiative it is moving into downstream value-added products. Sherritt Gordon and Inco are the world leaders in nickel-powder metallurgy. Falconbridge has focused its R&D on improving its productivity and reducing its SO_2 emissions.

There are substitutes for nickel today in most of its applications, and rapid developments in ceramics, titanium, and plastics could further affect nickel markets over the longer term. The future of the industry, therefore, will depend on the continual development of applications, and hence new

markets, for nickel alloys. For this reason, Western producers have established the Nickel Development Institute to promote new nickel products and defend existing ones.[21]

Semifabrication

In 1986, Canadian shipments of semifabricated nonferrous metals were $2.3 billion. Canada's imports of $919 million were almost double its exports of $558 million. The United States purchased 86 per cent of Canada's exports and supplied 80 per cent of Canada's imports.[22]

Rolling is the major semifabricating activity. It requires capital-intensive installations that only the larger corporations can afford. Extruding and casting, the other semifabricating activities, require less capital and can be done competitively by either large or small firms. A common characteristic of this and other commodity industries is that most products tend to be high-volume items with low profit margins.

A few large corporations in North America dominate the aluminum and copper rolling and extruding subsectors. In the aluminum subsector, the top four firms account for 84 per cent of shipments; in the copper subsector, 80 per cent. Corporate concentration in the "other metals" subsector is lower: the top four firms account for only 31 per cent of sales. Operating costs break down to 50-60 per cent for raw materials, 15-25 per cent for labour (higher for casting and extruding), and 5-10 per cent for energy.

The semifabrication subsector is considered relatively mature and has exhibited stable to moderate growth over the past 10 years. Closely tied to the automotive, construction, and consumer-products sectors, it is sensitive to business cycles.

The Canadian subsector, with the exception of specific products such as aluminum sheet, uses relatively short production runs to manufacture many products for the small domestic market. Canada's main competitors are U.S. plants, which are usually larger, more specialized, and more efficient, with longer production runs scaled to the larger U.S. market.

Canada's strength lies with companies that produce high-quality, competitive products for selected market niches. Although these firms are relatively small, they are able to effect line changes quickly and respond to orders on very short notice. Some of these firms are diversifying into new product lines; others are entering or expanding into the export markets.[23]

Transportation costs sometimes act as barriers to offshore competitors in North American markets. Nonferrous, semifabricated products tend to have a relatively low value per unit weight, so shipping costs can be a major factor in the delivered cost of the product. Thus, the most economical plant location is generally the one closest to the major market.[24] As a result, Canadian companies have some competitive advantages in the U.S. market over offshore companies.

Two important historical factors constrained the economic development of the Canadian sector. The first factor was foreign import duties. In general, Canadian products that were highly refined or upgraded faced higher tariff barriers in foreign markets. Fortunately, the Canada-U.S. Free Trade Agreement should make the export of finished goods to the U.S. much easier.

The second factor was the highly protected and small Canadian market. The absence of a more dynamic and demanding manufacturing sector discouraged innovation and downstream development, and it provided little motivation to do product R&D.

R&D and Technology Strategies in the Canadian Nonferrous-Metals Sector

Since the 1950s, Canada's share of world mineral markets has declined, and Canadian companies will continue to face competitive pressures over the next decade.

Ores, concentrates, and metals are commodities that are traded in a global market. To be successful, a company must be a low-cost producer. A primary strategy for Canadian companies to deal with competition in mineral commodities therefore must be to develop innovative processes that will give them productivity advantages and allow them to compete against producers with lower labour costs. New mining techniques and automated mining equipment have already increased the productivity of mines in Canada.

In the past, Canadian mining and mineral-processing companies concentrated on the upstream or commodity end of the metals spectrum. They developed world-class capabilities in geophysical exploration, mine development and mining techniques, and metallurgy. In fact, it seems fair to say that Canada is a world leader in these upstream core competencies.

The traditional image of hand labour using pickaxes to chip away rocks from an underground seam bears no resemblance to the present Canadian mining reality. Today, a miner is just as likely to be a computer operator. Indeed, as an experiment, underground excavating is taking place with no below-ground labour at all. An above-ground technician uses closed-circuit television to guide a remote-controlled drilling and excavation machine to the rock face. Computers above and below ground analyse the mineral deposit, position the excavation machinery, and control output and transportation to the surface.

Since the mining industry has experienced only limited growth, there has been a large drop in employment. However, new technology has allowed substantial productivity gains. For example, Inco needs only one-third as much labour as it did 20 years ago: its excavation labour force has declined from 24 000 workers to about 8000.

The Canada Centre for Mineral and Energy Technology (CANMET) commissioned an in-depth examination of R&D in the Canadian mineral sector in 1986-1987.[25] The study compared R&D in nonferrous metals in Canada with that in seven other countries — Australia, Finland, France, West Germany, Sweden, the United Kingdom, and the United States.

Overall, the CANMET study found that mineral-related R&D expenditures in Canada are low by international standards and have been declining in recent years, both in absolute terms and relative to other areas of R&D. This decline is also confirmed in a separate report by Canada Consulting Cresap that was commissioned by the Science Council of Canada. This study found that expenditures on nonferrous-metals R&D in Canada declined from $86 million in 1981 to $72 million in 1988 (in 1981 constant dollars).[26]

The nonferrous-metals sector in Japan, on the other hand, increased R&D expenditures from $457 million in 1981 to $813 million in 1988 (about 2 per cent of sales). Yet the Japanese output in copper, lead, and zinc, for example, is no greater than Canada's.

The CANMET study found that internationally, with few exceptions, both government and industry support for nonferrous-metals R&D fell during the 1980s. Nevertheless, Canadian efforts were small compared with those of other countries. For example, in terms of R&D spending as a proportion of *mining* GDP, Canada rated the lowest of the eight countries studied. Canada spent about 0.5 per cent of mining GDP on R&D, compared with 0.7 per cent for Australia and more than 2 per cent for most of the other countries. Moreover, in expenditures for basic R&D in metals, Canada

rated among the lowest as well. Canada spent about 1.4 per cent of base-metals GDP on R&D compared with, for example, 2.7 for West Germany and 4.1 per cent for Finland.[27]

Another survey of the research, development, and exploration spending of Canadian mining companies was conducted by the Mining Industry Technology Council of Canada (MITEC) in the fall of 1990. This study indicates that nonferrous-metals R&D in Canada has increased.[28] It can only be hoped this is a significant turnaround. The companies that responded account for about 90 per cent of the gross sales of nonferrous precious metals and minerals. Total R&D expenditures for these companies was $148.6 million in 1990, an increase of 16.5 per cent over the previous year. Their R&D spending was 0.86 per cent of gross sales of $17.3 billion. The breakdown of their R&D in mining, processing, and manufacturing projects is shown in Table 7.

Table 7. Canadian mineral producers' R&D expenditures by type (1989, 1990)

	1989		1990	
	R&D (thousands C$)	% of total	R&D (thousands C$)	% of total
Mining	32 575	25.5	45 412	30.6
Processing	74 545	58.4	71 582	48.2
Manufacturing	20 453	16.0	31 633	21.3
Total	127 573	99.9	148 627	100.1

Source: MITEC, "Research, development and exploration spending by Canadian mineral producers: a survey," Ottawa, 1990.

The data show that there has been a shift in the focus of R&D from processing to mining and manufacturing.

About 90 per cent of R&D in the industry is funded by the companies: most of the remainder comes from the federal government. In 1990, about 10 per cent of Canadian R&D funds were spent abroad.

There is a considerable debate in Canada on the relationship between R&D and exploration. Exploration expenditures by the companies surveyed amounted to C$446.1 million, representing 2.6 per cent of gross sales. Total expenditures were down slightly from the previous year. The industry funded more than 96 per cent of exploration; of the total, about 34 per cent was for overseas exploration. It is noteworthy that exploration expenditures for these mining companies, at 2.6 per cent of sales, are about three times larger than R&D expenditures, which represent 0.86 per cent of sales. The Canadian industry is on balance still commodity oriented, not value-added oriented.

The Canadian industry argues that these exploration expenditures should count as equivalent to R&D expenditures. Firms claim correctly that there is great financial risk in exploration, that it requires skilful management in an uncertain environment, and that it represents a necessary "technology and knowledge" investment for the future. These characteristics closely resemble those of R&D. If exploration were counted as part of R&D, then the total R&D expenditures as a percentage of sales by Canadian firms would be comparable to the equivalent combination for all other competitors, including Japan.

Moreover, it can be argued that Canada's leading capabilities in geophysical exploration and upstream techniques represent a comparative advantage in these activities. Indeed, a Canadian delegation to Japan apparently received Japanese congratulations on Canadian expertise in mining

generally — Japan could not compete in these upstream segments. And it is undoubtedly owing to Canada's concentration in geophysical exploration, mine development, and extraction techniques that the Canadian sector has a competitive edge in upstream activities.

The argument that exploration is in some sense equivalent to R&D is, however, debatable. Undoubtedly, exploration for new mineral deposits is necessary for future mining profits, but it needs to be put into a certain context — particularly in light of the development of new advanced materials and novel materials substitutions being brought about by foreign research. In this light, exploration is not equivalent to R&D.

The sector's emphasis on exploration, moreover, has been driven by the need for short-term survival when the sector had very limited cash. Low profits and high debt loads left little to be spent elsewhere. R&D required for long-term prosperity had to take a back seat.

Larger companies spend a greater proportion of their sales on R&D but less on exploration than smaller firms. Alcan spends the most by far on R&D. If Alcan is excluded from the Canadian Consulting Cresap data, industry R&D expenditures in nonferrous metals fall from 1.0 per cent to 0.7 per cent of sales. Much of Alcan's R&D expenditure relates to new-product development for niche markets.

A more detailed breakdown of R&D expenditures on nonferrous metals is given in Table 8, with some additional smaller companies included. The table shows a similar overall picture for 1990 data. Nonetheless, the pattern repeats itself: approximately 1.2 per cent of sales goes to R&D.

About 80 per cent of the Canadian industry's R&D expenditures are directed to process improvements; 20 per cent, to product development. More than half of the industry's R&D expenditures appear to be dedicated to adopting and adapting (see Appendix) existing technologies rather than to innovation or breakthrough research.[29]

In general, smelting and refining receive the most R&D effort, but Alcan's heavy downstream R&D effort skews the entire industry balance to semifabrication (see Table 9).

Public-Sector R&D

The major federal R&D funding for the mining and mineral industry is through CANMET, which supports R&D in mining, mineral processing, metals, and materials. The 1986-1987 funding in these four areas was $32 million (in 1981 dollars). About one-third of this supported R&D in mining; the remainder, metallurgy.[30] The share of this support that was devoted to nonferrous metals is not given. About 10 per cent of CANMET's support for mining and minerals funded Mineral and Development Agreements between the federal government and the provinces or territories from 1984 to 1991. CANMET's R&D budget has been declining over the past few years.

The National Research Council of Canada also conducts research on metals and metal applications. Other federal support is through Natural Sciences and Engineering Research Council of Canada (NSERC) grants.

More than half of mineral-related R&D funded by provincial governments comes from Quebec's Centre de recherches minérales (CRM), Canada's only provincial research organization dedicated exclusively to mining and minerals. Like CANMET, however, CRM has a declining budget for R&D. CRM's R&D expenditures peaked in 1983-1984 at $7.4 million and fell to $5.8 million in 1987-1988 (in 1981 dollars).[31]

Nonferrous-metals R&D is also conducted in mining and metallurgy departments in several universities and colleges, including University of Toronto, Queen's University, Université Laval, McGill University, McMaster University, the University of Alberta, the University of British

Table 8. Gross sales vs. R&D and exploration spending of nonferrous-metals firms (1990)

Canadian firm	Gross sales (thousand $)	R&D (thousand $)	R&D as % of sales	Exploration (thousand $)	Exploration as % of sales
Alcan	10 406 689	175 020	1.7	n/a	n/a
Inco	3 626 648	56 006	1.5	53 556	1.5
Falconbridge	2 032 500	12 400	0.6	51 200	2.5
Rio Algom	1 343 111	20 000	1.5	14 920	1.1
Cominco	1 403 479	12 900	0.9	36 963	2.6
Noranda Minerals*	2 668 000	15 200	0.6	119 000	4.5
Placer Dome	1 080 100	716	<0.1	78 900	7.3
Sherritt Gordon	345 250	7 689	2.2	—	—
Denison Mines	315 900	—	—	—	—
Hudson Bay M.&S.	420 083	740	0.2	8 372	2.0
Echo Bay Mines	338 939	165	<0.1	9 977	2.9
BP Resources	163 900	252	0.2	13 300	8.1
Cambior Inc.	138 820	—	—	12 105	8.7
Minnova Inc.	195 951	475	0.2	19 729	10.1
Nerco Minerals	45 200	—	—	467	1.0
	24 524 570	301 563	1.2	418 489†	3.0†

Source: Energy, Mines and Resources Canada; and *Canadian Mining Journal*, as quoted in Canada Consulting Cresap, "Mining and mineral processing: in-depth analysis," contract report prepared for the Science Council of Canada, 1990 (unpublished), 27-28.

* The Noranda R&D figure includes expenditures at the Noranda Technology Centre, HDRK, and associations.

† Alcan is excluded from this calculation, as this company does not disclose exploration expenditures, which are all overseas.

Table 9. Share of R&D expenditures by production function (1988)

	Mining (%)	Smelting and refining (%)	Semifabrication and fabrication (%)
Excluding Alcan	22	59	19
Including Alcan	10	44	46

Source: Canadian Consulting Cresap, "Mining and mineral processing: in-depth analysis," contract report prepared for the Science Council of Canada, 1990 (unpublished), 33.

Columbia, Technical University of Nova Scotia, and École polytechnique. R&D expenditures in Canadian universities and colleges totalled more than $20 million in 1986.[32]

Federal R&D is not insignificant when compared with the total private-sector R&D in nonferrous metals. The main sectoral R&D issue, however, is the business strategy of the large Canadian firms in the sector: at what level and in which direction does this strategy drive R&D overall?

Canadian R&D by Industry Segments

Each stage of production — mining, smelting and refining, semifabrication, and new-product development — has its own competitive and R&D drivers in the Canadian metals industry.

Mining R&D

A report for CANMET found that although overall Canadian expenditures on both mining R&D and mineral R&D were decreasing in the first half of the 1980s, mining R&D was in a particularly steep decline. The report argued that "Canada's good mineral potential and export dependency indicate that such a pattern is inappropriate for Canada."[33] Canadian mining R&D has a concentrated focus in process improvement to compete with low-cost competitors.

There have been some important Canadian mining-process improvements. Two examples are vertical-retreat mining (bulk mining) and sensors.

Case Study: Vertical-Retreat Mining or Bulk Mining

In traditional underground mining, a shaft is sunk to the lowest proposed working level, and then horizontal drifts and crosscuts are driven to reach the ore. The ore is removed from stopes (excavated "rooms"), but pillars of rock are left behind for support. A cycle of drilling and blasting fragments the ore, which is carried to the ore chute, dropped to the crushing level, crushed, and hoisted to the surface. A great deal of time and effort goes into shoring up service areas, approaches, and stopes to prevent rockfalls.

About 10 years ago, vertical-retreat mining, a type of bulk mining for massive deposits, was pioneered by Inco Limited in Canada. This method uses open stopes, which are more economical than smaller stopes because fewer pillars are required. Inco's test of open stoping proved it was a safer, easier mining method: it gave a 300 per cent improvement in productivity (in terms of tonnes per person per shift at a reduced capital cost); it concentrated all production activity on two levels (drilling and blasting occurred on the upper level, and the draw point, crusher, and hoist were located on the lower level); and because no pillars were left behind, secondary mining was unnecessary.

Since that successful test Inco Limited converted most of its nickel and copper mines to bulk-mining operations. Bulk mining, along with surface-plant modernizations, has increased productivity by 65 per cent for Inco's Ontario division. Inco also estimates that development of new mines by bulk methods can cost 60 per cent less. Inco's innovative strategy in mining has cut costs by approximately $140 million (in current dollars) per year since 1980, which is close to a 20 per cent cost reduction.[34]

Further developments in bulk mining should lead to more improvements in productivity and greater savings. Mining technologies, however, are only transferable to similar mines, and vertical-retreat mining is not appropriate for all metal deposits. Likewise, technologies developed elsewhere may not be appropriate for mines in Canada. For example, dramatic breakthroughs in South Africa are being made in deep gold mining, but these technologies are not applicable to Canadian gold mines.

Case Study: Sensors

Canada takes an adopt and adapt approach to new sensor technology in the mining sector. Most Canadian mining R&D groups tend to purchase off-the-shelf sensors from the United States, Japan, or Europe. Many of the sensors available in the United States have been developed for military or space applications and are quite suitable for the harsh Canadian mining environment. However, they are more expensive than standard-specification sensors, so they are not readily adopted in Canada. A popular direction in mining R&D in Canada is toward the application of current sensor technology to machine monitoring, control, and guidance:[35]

- *Monitoring* — Sensors are used to observe such parameters as the displacement, flow, temperature, and vibration of components. The signals that the sensors generate as a result of sensing changes in the system are collected by a computer-based data-acquisition unit. Using the data, one can analyse machine operations, mechanical problems, or the material (bedrock or ore) within which the machine is operating.[36]

- *Control* — This involves monitoring, as a first step, then analysis of the data online to determine the status of the machine. If any problems are detected, the computer control system sends instructions back to the machine to modify its performance. This process is referred to as a control feedback loop.[37]

- *High-level guidance* — This involves a high level of machine monitoring and control. In certain cases the computer system within the machine includes a map that controls the machine's operations. The signals from the sensors allow the machine to identify its location with respect to the physical constraints of its environment. Machines moving along the passageway in an underground mine can use ultrasonic detectors to determine the varying widths and heights, allowing for appropriate modifications to the operation. This is the highest level of guidance: its success depends on proper interpretation of the on-board and external sensor data. Examples of this type of system are few, for the technology has not yet proven reliable.[38]

- *Low-level guidance* — This level of guidance involves lasers, which project onto a highly reflective tape installed overhead along the desired machine path. Instructions are sent back to the guidance system to steer the machine. Research into these optical guidance systems is being conducted by the Noranda Technology Centre. Its automation group has been working jointly with the Canadian Centre for Automation and Robotics in Mining (CCARM) at École polytechnique to develop such systems for load-haul-dump (LHD) machines operating in Noranda's underground copper mines.[39] Inco is doing similar research.

Instrumenting certain mining machines with sensors and analysing the data have led to a new sensing capability. Drills, for example, are used in both underground and surface mines to make holes in the rock for exploration and loading (using explosives to break the material into manageable fragments from which the ore can be extracted). Sensors on the drill provide data, including details on the type and hardness of the rock being penetrated. This information is normally obtained by time-consuming and more expensive techniques. CCARM has been investigating techniques to extract geological data directly from monitored drill performance.[40]

Smelting and Refining R&D

Smelting and refining are capital-intensive operations — a greenfield smelting and refining operation can cost $500 million but would employ relatively few people. Firms generally update their processes

and technologies through incremental, cost-cutting R&D programs. At the same time, some firms are searching for the next state-of-the-art technology so that they will be able to invest wisely in new processes when the market and competitive conditions are right. As well, stringent Canadian environmental regulations require significant R&D effort by some types of metal refiners.

As a key platform in their competitive positioning and in light of their world-class expertise, leading Canadian companies tend to rely on in-house R&D for process innovations. The main drivers of process R&D continue to be cost reduction and productivity improvement. The pace of innovation has accelerated recently and is expected to continue accelerating. Accordingly, major refiners and smelters are devoting large portions of their R&D budgets (one- to two-thirds) to smelting and refining.[41]

Semifabrication R&D

Generally the pace of technological change in this relatively mature subsector of the Canadian industry is modest. Research focuses on upgrading current technologies through automation, computerization, robotics, and computer-aided design (CAD) and computer-aided manufacturing (CAM) systems.

R&D programs to find ways to cut costs continue to be crucial to the competitiveness of semifabrication firms. Large rolling companies, such as Alcan, Canadian Reynolds, and Noranda, also devote some in-house R&D to new-product development. Companies that are knowledgeable about new products on the market can produce them more easily.

New-Product R&D and Downstream Value-Added R&D

Canadian nonferrous-metals firms argue that they are not engaged in more new-product R&D because they have not found such ventures profitable. Executives in the nonferrous-metals sector in Canada are not the only ones to have indicated that they have had difficulty justifying more business investment in R&D in light of previous experiences. (See, as illustrations, Science Council of Canada Sectoral Technology Strategy Series, No. 2: *The Canadian Automotive-Parts Sector*, and No. 6: *The Canadian Petrochemicals and Resins Sector*.)

On the other hand, previous experience may not be a reliable indicator for the future. First, the large U.S. market is now much more accessible under Free Trade. Second, the worldwide trend toward lean production is providing novel opportunities for suppliers to move into new product areas and take on greater R&D responsibilities.

Lean production was pioneered by the Japanese automotive industry and is a major reason for the competitive edge Japanese firms have developed in that industry (see Science Council of Canada Sectoral Technology Strategy Series, No. 4: *The Canadian Automotive-Vehicle Sector*). In essence, in a lean-production system, suppliers develop components and subassemblies by themselves, rather than just providing "build-to-print" parts to the final assembler's specifications. This results in greater sharing of creative engineering tasks between final assemblers and parts firms and hence in major new R&D efforts by the suppliers (see Science Council of Canada Technology Strategy Series, No. 2: *The Canadian Automotive-Parts Sector*). In effect, lean production capitalizes on creative scientific and engineering talent throughout the supply chain. It is noteworthy that lean production is making the automotive market intensely competitive, but it is also creating new opportunities. Moreover, lean production is now applied in a broad range of sectors, not just in automotive.

In this new competitive environment, suppliers take an active role in research and new-product development. A few Canadian metals producers have responded by devising new applications for their metals. Two case studies are worth listing.

Case Study: Continuous-Cast Zinc Bearings

The R&D objective of Cominco's product group is to develop new applications to ensure end markets for its minerals. Cominco developed its continuous casting process for zinc ingots over 25 years. It also invested about $1 million over three to four years and a full-time technical team of three or four researchers to develop a zinc-bar stock that could be produced using this continuous casting technology. Cominco's continuous-cast zinc-bar stock is a substitute for some copper bearings in low-speed, high-load applications. The zinc bearings have better wear properties and are less expensive than copper bearings. Dedicated market-development staff are marketing the product through outside agents. The total market is estimated at $50-100 million per year.

Case Study: Nocolok — a Manufacturing Process

Nocolok is a brazing process for joining aluminum materials. The process was developed and patented by Alcan to replace chloride salt brazing, which is corrosive and costly. Alcan's Nocolok process has generated licensing fees, enhanced aluminum's stature in the automobile industry, and increased sales. Although its main use is in the automobile industry, it is also used in refrigeration (condensers, evaporators, tube-pipe joint assemblies), heat exchangers (radiators, heat cores, oil coolers, air-charge coolers), and electrical equipment (heat sinks, electrical-resistance heating elements). Alcan invested approximately $5 million in R&D to develop the process. Nocolok has been licensed to 35 manufacturers and fabricators, including General Motors, Ford, and Nippondenso.

Opportunities for R&D in the Canadian Nonferrous-Metals Sector

Canada, with its abundance of minerals, has developed a world-class nonferrous-metals sector. Opportunities may now arise from the fact that a few competing countries that have been leaders in mineral production and in related technologies (for example, the United States) may be at or near depletion of their mineral deposits. New competition in mining is developing, but this is mainly in countries that do not yet have mineral-research organizations, mining, processing, and metallurgical education programs, and expertise comparable to Canada's.

Canada is well placed to initiate and perform nonferrous-metals R&D and to innovate. Canadian metals companies are capable of providing technical expertise, practical know-how, and opportunities for on-site testing and development. Many Canadian universities have mining and metallurgy departments for basic and applied research and for training future generations of experts. Indeed, Canadian expertise in mine development, mining, and mineral processing has been marketed on occasion throughout the world.

But what evidence is there that Canada is suitably or fully exploiting these advantages? Industry support for mineral-related R&D in Canada is low and was declining until recently. Government support is also limited, but without stronger industry commitment and partnership, it is not clear how useful further help would be. R&D by the Canadian nonferrous-metals sector in 1987 stood at half the Organization for Economic Co-operation and Development (OECD) average. An important point is that Canadian firms in the nonferrous-metals sector, unlike those in all too many other sectors, are big enough to mount major technology efforts.

Mining

There will be opportunities in new continuous-mining technology, likely to be the next major breakthrough. Continuous mining uses nonexplosive methods for breaking rock and for the continuous removal of the broken rock to the mill. New machine concepts and new cutting technologies are needed.

Many new cutting techniques involving heat, projectiles, sonic waves, chemicals, lasers, water jets and others have been tried experimentally, but none has been completely successful in practice. Several machines are being developed with new cutting technology, but the more interesting work has not reached the public domain. A breakthrough in this area could fundamentally change the nature of the mining industry.[42]

Continuous mining of hardrock is being studied by the Inco, Falconbridge, and Noranda consortium known as HDRK. HDRK focuses on long-term research and capital-intensive development of mining equipment and methods. In 1988, HDRK's budget was $2.8 million.[43]

Other opportunities will be in environmental R&D. Over the last few years considerable attention has been focused on the environmental damage caused by industries in the sector. Environmental regulations have motivated 25-30 per cent of all mineral-related R&D in Canada in recent years. One key environmental challenge is acid mine drainage (AMD), a problem that is simple to describe but difficult to solve. Sulphide tailings and waste, when exposed to oxygen and moisture, oxidize and generate acid, which then leaches heavy metals into receiving waters. Collecting and treating the effluent during a mine's operation can control AMD. But no one has sufficient knowledge yet to guarantee safe, stable, long-term, economical management of waste material once the site is decommissioned. Some abandoned mines that have been dormant for years may suddenly generate

AMD. Preliminary evaluations have identified at least 15 000 hectares of acid-generating mine waste and tailings, mainly at operating mines. An equal quantity might be created in the next 20 years. The total cost to stabilize existing and new deposits could be more than $3 billion over the next 20 years.[44]

A potential opportunity in mining and beneficiation in the more distant future is the use of biotechnology. At present the nonferrous-metals industry uses mostly physical processes; biotechnology is used for environmental problems and to a limited extent for heap leaching of gold. Canadian mining firms should avail themselves of CANMET's expertise in mining biotechnology and take advantage of biotechnology as a possible business opportunity.

Although not an R&D opportunity, one business strategy that Canadian firms could consider is to "spin-off" their exploration units into separate firms or subsidiaries. To some extent this has already happened. In fact, many exploration efforts of large mining companies are in conjunction with, or as a follow-up to, the grassroots work of the so-called junior exploration companies, which have been responsible for many of the ore discoveries of the last 20 years or so. Thanks to Canada's deserved reputation in geophysical services, such stand-alone firms or subsidiaries would do well in export markets. This would parallel, to a certain extent, what has happened in the oil and gas and electric-power sectors (see Science Council of Canada Sectoral Technology Strategy Series, No. 5: *The Canadian Oil and Gas Sector*; No. 12: *The Canadian Electric-Power Sector*; and No. 13: *The Canadian Consulting-Engineering Sector*.)

Smelting and Refining

A possible R&D opportunity in smelting and refining is the development of hydrometallurgical technology to complement conventional pyrometallurgical processes. The application of hydrometallurgical technology to smelting and refining has been much slower than once expected, because in many instances it is not cost competitive. However, this technology may enhance the recovery of by-products, such as silver in zinc deposits. At present, relatively low prices for silver mitigate against co-recovery techniques. Many firms may feel that investments in new refining technologies are accordingly rather questionable. The real challenge is to develop a new generation of processes, whether hydrometallurgical or pyrometallurgical, that produce satisfactory products with minimal emissions, effluent, and solid wastes, meet environmental-protection standards, and face the recycling issue head on.

Case Study: Indium

Indium is a white metal used in the electronics sector for such products as television screens and calculators. Falconbridge found that its Kidd Creek mines, purchased in 1986, had indium-rich material that was being left in tailings. In 1987, the Falconbridge in-house R&D team began a project to recover indium from Kidd Creek copper and zinc mines. Falconbridge attempted to purchase a process technology, but none was found to be as up-to-date as the company wanted. Falconbridge spent $2.5 million over two years to develop a process and build a pilot plant. Falconbridge scientists and engineers have developed what they believe is the best technology in the world for indium recovery. A new indium plant is now being built for $20-22 million. It will produce indium and improve copper, nickel, and zinc recovery.

Falconbridge entered into a three-year contract with Indium Corporation of America (ICA) to sell its product in exchange for market information. Marketing and distribution costs will be based on a percentage of sales. Indium is produced by several small producers and sold through marketers such

as ICA that buy impure metals and refine and sell them. The world indium market was about $10 million in 1987. Falconbridge estimates that it will attain a 30 per cent share.

This case illustrates how a firm can reduce both the cost and the risk of entering new markets. Specifically, Falconbridge is using a short-term arrangement with a distributor rather than making a potentially risky up-front investment in a sales, marketing, and distribution infrastructure. Additionally, the short-term contract gives Falconbridge valuable time to learn more about the market, its competitors, and the customer base.

Manufacturing and Product Development

The greatest vulnerability of the Canadian nonferrous-metals sector is the potential for substitute materials to make entire applications of base metals obsolete: for example, aluminum has already replaced copper in many applications. A strategy of developing value-added products would reduce reliance on commodity markets:

> One of the striking features of the Canadian economy, uncharacteristic of an industrialized country, has been the dearth of linkages between the natural resource sector and industries based on finished products. . . . This failure to build capacity to add value to primary commodities not only limits employment opportunities in Canada but also makes it much more difficult for Canadian mineral producers to cope with an uncertain market.[45]

The logical way for Canadian nonferrous-metals firms to make profitable investments in new-product development is by establishing linkages with downstream customers such as construction companies and manufacturing firms (for example, automotive-parts companies, battery producers, electrical and electronics firms). Such linkages would have to be extensive, ranging from joint strategic planning to mergers and acquisitions.

Some companies are already moving in this direction. A case in point is Inco. Inco's nickel powders represent a small but growing part of the company's total production. These powders are used for special catalysts, hard metals, steel alloy parts, and batteries. In recent years, market and technological changes have increased rapidly, threatening Inco's powder market. For example, many new battery designs have evolved, including some based on lithium electrodes. Inco formed a separate business unit, Inco Specialty Powder Products, to link relevant marketing, production, and research activities. In 1990 Inco spent $4 million on special-products R&D to adapt Inco's specialty powder products to meet the future demands of its customers worldwide.

Some nonferrous-metals firms do work with their customers on new-product development. But consider that leading Canadian firms in the automotive-parts sector are moving from investing virtually zero in R&D 10 years ago to investing in the range of 2-5 per cent of sales in R&D today. This suggests many more opportunities exist.

Downstream linkages represent a substantial opportunity for Canadian nonferrous-minerals companies to grow. Moreover, these companies seem to have the cash flow from mining and smelting operations to support new technology efforts, whereas Canadian firms in other downstream sectors, such as automotive parts, machinery, and electronics, lack capital and need financing (see Science Council of Canada Sectoral Technology Strategy Series, No. 2: *The Canadian Automotive-Parts Sector*; No. 10: *The Canadian Machinery Sector*; and No. 14: *The Canadian Electronics Sector*).

On balance, increased activity in the new-product (downstream) segment represents the best strategy for growth, increased profits, and employment in the nonferrous-metals sector. The development of value-added products in this sector in the past has been deterred by the high foreign, particularly U.S., tariffs for semifabricated and finished products. The recent trend toward lower tariffs

and the Free Trade Agreement should remove many of the barriers to Canadian export of semifabricated and new products. However, new investments, both to conduct necessary R&D and to establish linkages with downstream customers, will be required to develop such a strategy in this sector.[46]

Toward an Agenda for Action: Three Views

There are three broad views on the sector's future development.[47] Each implies a different scenario for R&D:

- *Traditional* — The traditional view emphasizes firms' "sticking to their knitting" and doing what they do well, in other words, focusing on upstream activities such as mining and extraction. This means Canadian firms will have to invest more intensively in mining overseas to be strong global players. Exploration and mine development are presently what Canadian firms do best. They should continue to concentrate development on these activities and core competencies, which give a relatively low priority to R&D. The traditional view also includes a reluctance to compete with customers. For instance, zinc producers do not move into the zinc die-casting business. However, in this scenario metals firms are still responsive to customers' general needs. An example is Inco's work on semifabricated "blanks" for gas-turbine engine blades. Customers do the finishing on the rough-hewn blanks produced by Inco. By stopping at this stage of production, Inco can still sell its semifabricated products to all major jet-engine manufacturers.

- *Incremental* — This alternative view supports the upstream agenda but also stresses more value-added production and a need for further integration with downstream activities. The emphasis is on incremental advances in existing technologies and core competencies, with a few small acquisitions and alliances inside the core business. This scenario gives a higher priority to R&D. Noranda provides an example, with its stress on further value-added production, its acquisition of American Racing Equipment Company, its search for joint ventures and strategic alliances, including those with other international mining firms, its fully integrated aluminum business, its production of zinc powder for dry-cell batteries (a very demanding value-added product), and its R&D program for zinc products and applications.

- *Downstream* — A third view is to build on upstream activities but to stress downstream development, with alliances and acquisitions outside the old core business and competencies, as necessary and fundamental. In this scenario, there is a need for both R&D and innovative new products. Even new organizations are required to work closely with customers to develop new materials and products.

Let us consider in a little more detail the third view, insofar as it involves a distinctly new direction and a different scenario for R&D.

The downstream view suggests that Canada can learn from the Japanese: how their firms design for, and respond to, the end market; and how their firms form *keiretsus* and other downstream "industry strategic linkages." Sumitomo Metals and Mitsubishi Metals are examples of firms moving downstream: both were once primarily mining companies, but now they have expanded considerably through downstream integration. The Sumitomo-Mazda alliance is an excellent illustration of "tiering" between a nonferrous-metals firm and a client (automotive) industry. Could Canadian firms emulate this linkage to create a similar synergy? Should they attempt to do so? What barriers need to be removed or overcome? The scenario warrants debate. Certainly the current high interest and exchange rates discourage the necessary new investments.

Should Canadian nonferrous-metals companies integrate downstream? In the downstream view, the argument is that they must.

The German development of silicon as a new material, vital to the electronics industry, illustrates downstream vertical integration. Today, German firms practically control the silicon-material industry: they have enormous development capabilities and well-established downstream connections to client industries, notably electronics.

Examples from Canada include Alcan and Sherritt Gordon. Alcan has expanded its downstream Alcan Enterprises unit, which groups its 15 manufacturing divisions in North America. The unit is obtaining a 20 per cent return on capital. Using only 6 per cent of Alcan's capital and 10 per cent of its employees, the unit generates 20 per cent of Alcan's global sales revenue.[48] The fabrication businesses are expected to grow by 6 per cent a year to 2000, compared with 2.5 per cent a year for unprocessed aluminum.

Sherritt Gordon has moved distinctly toward a downstream orientation. A simultaneous "market pull" and "technology push" set its R&D priorities and plans. Sherritt Gordon also licenses technology overseas for $4 million a year, which helps to pay for its own investments in R&D; and it has cooperative support from the federal and Alberta governments (at $30 million each). For every dollar it invests in R&D, it spends an additional dollar on capital investment. Its internal "hurdle" for return on investment (ROI) is 30 per cent for new-product development.[49] It also produces specialized coinage materials.

There are many options for establishing downstream linkages. Examples are partnerships, alliances, and acquisitions. In a partnership, the metals firm could cooperate directly in research with a client. In an alliance, research tasks could be shared to achieve complementarity with client firms to avoid duplication. In an acquisition, a nonferrous-metals firm could obtain a controlling interest in a client firm, thereby gaining direct knowledge of the needs of its client. The metals firms, in this scenario, actively seek out linkages that place them in a direct relationship with the ultimate user of their materials. A management challenge is to find an interface with the client firms that both sides can respect. A critical element is improved appreciation of the eventual (end-product) market. An example of this scenario at work is Japanese metals companies developing aluminum structures for automotive-vehicle bodies.

Conclusion

With its relatively heavy orientation toward an upstream strategy — one that does not require a large investment in R&D (as opposed to exploration) — the Canadian sector's R&D performance looks rather weak compared with the massive expenditures for R&D by the leading Japanese nonferrous-metals companies. But the Japanese companies, confronting very different circumstances in their large and technologically sophisticated domestic market, focus primarily on a downstream strategy, nurtured by close partnerships with end-users that drive their strong R&D performance.

Canada's world-class nonferrous-metals sector, highly successful in earlier decades, is now at a significant crossroads. What is the appropriate path to follow? The sector is dominated by a few large, vertically integrated firms that are world leaders in their upstream core competencies. Several firms follow the path focused on exploration, mine development, extraction, smelting, and refining. On this path the firms' goals are to limit costs and raise productivity to become low-cost producers. Maintaining their global competitiveness in mineral production has proved very difficult in the conditions of the past decade.

Several other firms have attempted (some more successfully than others) to follow a path toward further value-added production by moving into related downstream areas. On this path, the firm's goals are to compete by offering products differentiated by higher quality, superior performance, or other characteristics.

It is doubtful that the nonferrous-metals sector can be sustained at its present scale within Canada over the next decade by maintaining a primarily upstream strategy. The strong likelihood is that pressures will drive investment in mining operations and competencies overseas. But can the sector sustain itself and attract the necessary investment capital to move markedly downstream and make the strategic partnerships, acquisitions, mergers, or alliances with end-users that will drive a dynamic R&D and build a different set of core competencies? More importantly, can it afford not to?

The downstream path will require large capital investments, mergers and acquisitions, imaginative R&D, strong leadership, and a concerted effort by all levels of government to provide supportive policies. If the sector is to survive profitably the next 10 years, a strong sense of urgency should permeate the national debate and discussion on how to support and sustain those firms taking this path.

Appendix: Framework for Technology Strategies

As part of the methodology for analysing each sector, the Science Council of Canada sought whenever possible to assess company technology strategies according to the following framework:

	adopt and adapt	innovation	breakthrough
product			
process			

Strategy Classes

Adopt and Adapt: Acquire a technology and adapt it to serve as a competitive platform.

Innovation: Incrementally improve on winning technology to get greater market share or maintain competitive edge.

Breakthrough: Seek to create a discontinuity in the marketplace, thereby leaping ahead of the competition.

The company case studies generally looked for at least seven key dynamics influencing a company's technology strategy:

- three internal dynamics:
  - competitive position,
  - capacity for innovation, and
  - strategy and vision; and
- four external dynamics:
  - customer demands,
  - competitive rivalry,
  - supply condition, and
  - available technology.

The methodology also incorporated essentially a three-step process for each sector. In the first step one or more contractors analysed the main elements in the competitive and R&D performance of the Canadian sector and its leading foreign competitors. The second step included evaluation of the contract report(s), discussion with contractors and other experts, additional in-house research, and preparation of a draft Council report. In the third step, external reviewers commented on one or more drafts of the Council report, which were then revised and refined as required, drawing on the advice of the liaison person for that sector on the Steering Committee (see Acknowledgements). For some sectors, the third step also involved several external reviewers in a small workshop, one part of which

helped define some elements of a potential action plan for the sector. The report was then submitted for final approval to the Executive Committee of the Science Council, before being forwarded to Industry, Science and Technology Canada.

Notes

1. John E. Tilton, "Changing trends in metal demand and the decline of mining and mineral processing in North America," *Resource Policy* 15, No. 1 (March 1989): 13.

2. Ibid., 18.

3. Raymond F. Mikesell and John W. Whitney, *The world mining industry: investment strategy and public policy* (Boston: Allen & Unwin, 1987), 167.

   The nature of trends in real metals prices is controversial. Data supplied by the Mining Association of Canada indicate that the Canadian real metals price index dropped from 119.5 in 1965 to 109.6 in 1990 (1971 = 100). Because ordinary business cycles affect price levels, cyclical "peaks" and "valleys" need to be compared with corresponding points in earlier or later cycles. Since the 119.5 in 1965 was close to a peak value, it should be compared with (say) 1989, which was also close to another cyclical peak, having an index value of 132.55. This comparison shows a gain in real prices, not a decline. But what about comparing the 1965 index with the 1986 index, which was a healthy overall economic year? The Canadian metals price index in that year stood at 93.7, a sharp drop from 20 years earlier. The index stood in the 70s during most of the late 1950s.

   Taking the last 10 years, the drop has been pronounced. The price index declined from 178.85 in 1980 to 109.57 in 1990. On balance, it seems real prices are falling, although judicious selection of years can show different results.

4. Op. cit., 20.

5. Tilton, op. cit., 20.

6. Ibid., 18.

7. Ibid., 347.

8. Mikesell and Whitney, op. cit., 57.

9. Ibid., 174.

10. Ibid., 173.

11. Corporate Directions Inc., "The Japanese nonferrous metals industry, industry structure and technology strategies," contract report prepared for the Science Council of Canada, 1990 (unpublished), 20.

12. Ibid., 31.

13. Ibid., 36.

14. Ibid., 41.

15. Simon Hunt, "World supply-demand pattern for metals in the 1990s," in *Prospects for Minerals in the 90s*, edited by Peter Richardson and Renka Gesing, (Kingston: Queen's University, 1988), 58-59.

16. Statistics Canada, *Canada Year Book 1990*. (Ottawa: Minister of Supply and Services Canada, 1989), 10-1.

17. Canada Consulting Cresap, "Mining and mineral processing: in-depth analysis," contract report prepared for the Science Council of Canada, 1990 (unpublished), 6.

18. Margot Wojciechowski, "Research and development in the mineral sector," Executive Summary. Report prepared for CANMET (Kingston, Ont.: Centre for Resource Studies, 1989), 19.

19. Robert Telewiak, Nonferrous Division, Energy, Mines and Resources, personal communication.

20. Canada Consulting Cresap, op. cit., 11.

21. Industry, Science and Technology Canada, "Nickel smelting and refining," (Ottawa: Industry Profile, 1988 series), 4.

22. Industry, Science and Technology Canada, "Non-ferrous semi-fabricated products" (Ottawa: (Industry Profile, 1988 series), 1.

23. Ibid.

24. Ibid.

25. Margot Wojciechowski, op. cit.

26. Canada Consulting Cresap, op. cit., 24.

27. Margot Wojciechowski, op. cit., 9.

28. MITEC, "Research, development and exploration spending by Canadian mineral producers: a survey," (Ottawa: Fall 1990). Quoted with permission.

29. Canada Consulting Cresap, op. cit., 34-35.

30. Ibid., 17.

31. Ibid., 5.

32. Ibid., 6.

33. Ibid., 15.

34. Canada Consulting Cresap, op. cit., 61, in conjunction with a personal communication from Inco to the Science Council.

35. Dr. Jonathan Peck, Laboratory Manager/Associate Professor, Canadian Centre for Automation and Robotics in Mining (CCARM), Department of Mining and Metallurgical Engineering, Interview, McGill University, June 1991.

36. Ibid.

37. Ibid.

38. Ibid.

39. Ibid.

40. Ibid.

41. Canada Consulting Cresap, op. cit., 70.

42. Marilyn Scales, "The next decade of change," *Canadian Mining Journal* (December 1989): 14.

43. Canada Consulting Cresap, op. cit., 62.

44. C. George Miller, "Mine Environment Neutral Drainage (MEND) program," *Canadian Mining Journal* (August 1989): 35.

45. David G. Haglund, ed., *The New Geopolitics of Minerals: Canada and International Resource Trade* (Vancouver: The University of British Columbia Press, 1989), 42.

46. Canada Consulting Cresap, op. cit., 72.

47. These three views were represented at a Science Council of Canada meeting with various members of the nonferrous-metals sector, held in Toronto, October 1991.

48. Kevin Dougherty, "Alcan's powerful mystery man," *Financial Post* (11 November 1991): 13.

49. Personal communication from Sherritt Gordon to Science Council of Canada.